Great Basin Naturalist 52(2), 1992, pp. 189–193

VEGETATION ASSOCIATED WITH TWO ALIEN PLANT SPECIES IN A FESCUE GRASSLAND IN GLACIER NATIONAL PARK, MONTANA

Robin W. Tyser[1]

Key words: alien flora, Glacier Park, Festuca *grasslands.*

The presence of alien flora in natural area grasslands of the Great Basin and surrounding areas is of considerable concern, given the widespread success of alien flora and associated decline of native species in this region (Young et al. 1972, Mack 1986, 1989). Surveys of indigenous bunchgrass communities in northern Rocky Mountain national parks have detected the occurrence of several alien plant species (Koterba and Habeck 1971, Stringer 1973, Weaver and Woods 1985, 1986, Tyser and Worley 1992). In addition, alien species have commonly been used to revegetate human-disturbed sites such as roadsides and housing areas in national parks. Livestock-related introduction of Eurasian pasture grasses by private outfitters is also known to have occurred (Glacier National Park Records 1939). However, in spite of these observations and practices, the effects of alien vegetation in natural area grasslands of this region remain poorly studied.

This study compares the indigenous vascular flora and cryptogamic ground cover associated with two alien species, *Centaurea maculosa* Lam. (spotted knapweed) and *Phleum pratense* L. (common timothy), that have invaded a fescue grassland in Glacier National Park, Montana. *C. maculosa,* now a noxious rangeland invader throughout the Pacific Northwest (Watson and Renney 1974, Lacey 1989), was first detected in the park in the mid-1960s (R. Wassem, personal communication). Earlier observations have shown that this species is expanding into grasslands adjacent to roadsides in the park and reducing species richness (Tyser and Key 1988). The impact of *C. maculosa* on the cryptogamic ground crust—of potential importance in soil stabilization, moisture retention, and nitrogen fixation (Rychert and Skujins 1974, Anderson et al. 1982, Brotherson and Rushforth 1983)—has not yet been considered, nor has the impact of *C. maculosa* been compared to that of other alien species. *P. pratense* is widely distributed throughut the park's grasslands. Unlike *C. maculosa,* this species appears to have been intentionally seeded in grasslands by outfitters before the 1940s and along roadsides by park personnel before the 1980s (D. Lange and J. Potter, personal communication).

Study Site and Methods

The ca 10-ha study area, located adjacent to Going-to-the-Sun Highway in the St. Mary drainage of Glacier National Park, Montana, is fairly topographically homogeneous, i.e., clearly defined drainage channels are absent, and slope, exposure, and substrate texture are relatively uniform. The study area includes a large (ca 5 ha), irregularly shaped stand dominated by *Phleum pratense* and a small (ca 0.1 ha) stand adjacent to the roadside ditch dominated by *Centaurea maculosa.* The *Centaurea* stand extends >20 m away from the ditch and is not part of the road-cut corridor. The remaining portion of the study site is composed of a stand of native *Festuca* grasses and associated vegetation in which invasion by alien species has been minimal. Though no homesteading is known to have occurred in the study area before establishment of the park in 1910, this area was likely used as summer pasture for concession trail horses from approximately 1915 to 1940 (B. Fladmark, personal communication). The study area has not been used for stock grazing since that time. Otherwise, there is no indication that any of the areas sampled in the three stands have been subjected to anthropogenic disturbance

[1]Department of Biology and Microbiology, University of Wisconsin–La Crosse, La Crosse, Wisconsin 54601

since the park was established. In addition, no fires have been recorded in or near the study area since 1910. A cryptogam ground layer composed of small lichens and mosses covering undisturbed soil surfaces is commonly present. Qualitative observation suggests that mosses are the dominant element in this layer. Mean annual precipitation in the study area is ca 65 cm (Finklin 1986).

In each stand, vegetation was sampled using 20 × 50-cm quadrat frames along two transects placed in representative areas. Within each quadrat, presence of all vascular species was determined, and the canopy cover of each vascular species and the surface cover of the cryptogamic ground crust were estimated to the nearest percentage. A stratified random sampling procedure was used in which quadrats were randomly placed along transect segments of fixed length. For the *Centaurea* stand, transects were 20 m long, and one quadrat was randomly placed within each 2-m segment (N = 20 quadrats). For the *Phleum* and *Festuca* stands, transects were 100 m long, and one quadrat was randomly placed within each 5-m segment (N = 40 quadrats per stand).

Five vegetation measures were calculated for each individual quadrat: (1) vascular species cover diversity using the Shannon-Wiener index ($H' = -\Sigma p_i \log p_i$), (2) vascular species richness, (3) cumulative canopy cover of native forb species, (4) cumulative canopy cover of native grass species, and (5) surface cryptogam cover. One-way ANOVAs were used to assess among-stand differences for each of these quadrat measures. With the exception of the diversity measures, data did not meet parametric assumptions (normal distributions, homogeneous variances) and could not be transformed using standard logarithmic, arcsine, or square root transformations. Therefore, data were analyzed by the Kruskal-Wallis nonparametric one-way ANOVA procedure as described by Conover and Iman (1983). The Tukey multiple comparison procedure, applicable to both parametric and nonparametric ANOVAs (Conover and Iman 1981), was used to make pair-wise among-stand comparisons. Species nomenclature follows that of Hitchcock and Cronquist (1973).

RESULTS AND DISCUSSION

Prominent graminoid and forb species in the *Festuca* stand included *Achillea millefolium, Carex spp., Festuca idahoensis, F. scabrella, Gaillardia aristata,* and *Lupinus sericeus* (Table 1). Species composition of this stand was similar to prairie communities described elsewhere in the Pacific Northwest, e.g., the *Festuca scabrella/F. idahoensis* association of western Montana (Mueggler and Stewart 1980), the *Festuca/Danthonia* prairie of Alberta (Stringer 1973), and the Washington Palouse prairie (Daubenmire 1970). Estimated surface cover of the cryptogam layer in this stand was relatively high, characteristic of western bunchgrass prairies (Daubenmire 1970, Mack and Thompson 1982). Three alien species were sampled within the *Festuca* stand, though total cover of these species was <1.0%.

Significant among-stand variation occurred for all community measures (Table 2). Each of these measures was lowest in the *Centaurea* stand. Canopy cover of native forbs and cryptogam ground cover in this stand were particularly low, only ca 18% and 4%, respectively, of the corresponding *Festuca* stand measures. Thus, effects of the *Centaurea maculosa* invasion on the native flora in the study site appear to be relatively severe. The impact of this species is even more impressive considering its relatively recent entry into the park.

All but one of the *Phleum* stand measures were significantly lower than those of the *Festuca* stand (Table 2). Canopy cover by native graminoids in the *Phleum* stand was reduced to about 50% of its level in the *Festuca* stand. However, forb cover differences between these two stands were not statistically significant (Table 2). Three species (*Achillea millefolium, Agoseris glauca,* and *Lupinus sericeus*) were among the four forb species with highest canopy cover in each stand, suggesting that the forb components of these two stands were relatively similar. These observations suggest that *Phleum* invasion has affected native graminoids more than native forbs. It should also be noted that while mean quadrat richness was lower in the *Phleum* stand (Table 2), eight more species were recorded in this stand than in the *Festuca* stand (N = 59 vs. N = 51; see Table 1). Thus, different *Phleum* vs. *Festuca* richness patterns may occur if comparisons are derived from sampling units larger than the 0.1-m^2 quadrats used in this study.

Cryptogam cover in the *Phleum* stand was approximately 50% lower than in the *Festuca* stand (Table 2). Mack and Thompson (1982)

TABLE 1. Canopy cover (%) estimates of species within the *Festuca, Phleum,* and *Centaurea* stands. ° = alien species.

Species	*Festuca*	*Phleum*	*Centaurea*
GRAMINOIDS			
Agropyron caninum	0.4	0.6	
Agropyron spicatum	0.3	0.3	
Carex spp.	12.3	5.6	9.3
Danthonia intermedia	4.2	0.9	
Festuca idahoensis	9.2	4.3	0.2
Festuca scabrella	7.1	4.1	2.1
Helictotrichon hookeri	0.9	<0.1	
Koeleria cristata	1.4	0.4	<0.1
Phleum pratense°	0.2	38.4	0.7
Poa juncifolia		<0.1	
Poa pratensis°	<0.1	0.9	1.0
Stipa occidentalis	3.7	2.1	
Stipa richardsonii	0.1	0.8	
FORBS			
Achillea millefolium	11.7	8.6	0.8
Agoseris glauca	4.0	4.3	
Allium cernuum	0.1	<0.1	
Amelanchier alnifolia	0.3	0.9	0.5
Androsace septentrionalis	1.0	0.3	
Anemone multifida	1.4	1.0	<0.1
Antennaria microphylla	0.8	0.3	1.7
Arabis glabra		<0.1	
Arabis nuttallii	0.2	0.1	<0.1
Arctostaphylos uva-ursi	0.4	0.2	
Aster laevis		1.8	0.9
Berberis repens	0.1	0.6	0.3
Campanula rotundifolia	0.5	1.0	<0.1
Castilleja cusickii	0.3	<0.1	
Centaurea maculosa°			62.0
Cerastium arvense	4.0	3.1	0.7
Collomia linearis		<0.1	
Comandra umbellata	0.5	0.3	
Epilobium angustifolium		0.5	
Erigeron subtrinervis		1.5	
Erysimum inconspicuum		0.3	
Fragaria virginiana	<0.1	0.7	
Gaillardia aristata	1.9	0.6	<0.1
Galium boreale	0.6	1.8	0.2
Gentiana amarella	1.3	0.7	
Geranium viscosissimum	<0.1	1.2	
Hedysarum boreale	0.5		
Heuchera cylindrica	0.1	0.2	0.2
Hieracium umbellatum			0.2
Juncus balticus		1.0	
Lathyrus ochroleucus		0.2	
Lithospermum ruderale	1.9	3.9	0.7
Lomatium triternatum	1.0	2.4	0.3
Lupinus sericeus	5.6	6.0	<0.1
Monarda fistulosa		0.6	
Orthocarpus tenuifolius	1.2	<0.1	
Oxytropis campestris	2.8	0.9	
Oxytropis splendens	0.3		
Penstemon confertus	0.8	1.9	0.7
Potentilla arguta	<0.1	1.1	
Potentilla gracilis	<0.1	0.4	0.3
Potentilla hippiana	0.5		
Prunus virginiana		0.1	
Rhinanthus crista-galli	0.9	0.4	
Rosa woodsii	1.3	2.3	0.2
Silene parryi	0.4	0.1	<0.1
Sisyrinchium angustifolium	0.2	0.4	
Solidago missouriensis	1.6	1.8	0.2
Taraxacum officinale°	0.2	1.4	0.3
Tragopogon dubius°	<0.1	0.4	
Vicia americana		1.6	1.0
Zigadenus venenosus	<0.1		

TABLE 2. Among-stand comparisons of quadrat means for five vegetation measures. N = 40, 40, and 20 quadrats, respectively, for the *Festuca, Phleum,* and *Centaurea* stands.

	H'	Richness	Native graminoids	Native forbs	Cryptogam crust
Festuca°	0.966^{a}	14.8^{a}	39.5^{a}	48.4^{a}	28.9^{a}
Phleum	0.872^{b}	12.9^{b}	19.2^{b}	55.1^{a}	15.1^{b}
Centaurea	0.385^{c}	7.2^{c}	11.6^{c}	8.8^{b}	1.3^{c}
$F_{2,97}$	90.084	41.150	53.807	40.896	31.835
P	<.001	<.001	<.001	<.001	<.001

°Within each vegetation measure, means with different letters differ significantly from one another ($P < .05$, Tukey multiple comparison tests).

suggest that the extensive rhizome-tiller mats of Eurasian grasses limit cryptogam colonization sites, which may account for the reduced cryptogam cover observed in the *Phleum* stand. A large elk herd overwinters in the St. Mary valley grasslands in which the study area was located (Martinka 1983). Thus, it is possible that elk trampling/grazing may reduce cryptogam cover and facilitate *Phleum* invasion.

The role played by pre-1940 horse grazing in the occurrence of *Phleum* in the study site cannot be assessed. However, the prominence of this species some 50 years after the cessation of horse grazing does indicate that ongoing livestock grazing is not necessary for its persistence. The more recent *Centaurea maculosa* invasion in the study site and in other fescue grasslands in the park (Tyser and Key 1988, Tyser and

Worley 1992) suggests that livestock grazing is not a prerequisite for successful invasion of natural areas by this species. The success of both *P. pratense* and *C. maculosa* in the study site suggests that mechanisms proposed for the success of alien flora in agro-systems, e.g., rapid colonization of disturbed sites, structural and physiological adaptations to grazing and trampling, and low palatability (Mack and Thompson 1982 and references therein, Lacey et al. 1986, Locken and Kelsey 1987, Kelsey and Bedunah 1989), may also operate in natural area systems. In addition to overwintering elk, diggings of other native herbivores, especially ground squirrels (*Spermophilus columbianus*), were common throughout the study area. At any rate, though the status and impacts of *C. maculosa* and *P. pratense* require additional research, this study shows that the potential effects of these species—particularly that of *C. maculosa*—in natural area bunchgrass prairies need to be seriously contemplated.

Reduction of *Phleum pratense* is not a realistic option in Glacier National Park or other natural areas in which this species is now widely established. Perhaps the most reasonable recommendation for this species and other Eurasian grasses is simply that resource managers not use these species for revegetation (see also Wilson 1989). *Centaurea maculosa*, though potentially more ecologically disruptive than *P. pratense*, is at an earlier stage of invasion in the park and probably in other natural areas in this region as well. Thus, the fate of this species may yet be influenced by appropriate resource management actions.

ACKNOWLEDGMENTS

I thank Tom Jacobsen and Andy Tyser for their assistance with fieldwork, Andy Matchett for statistical advice, and Glacier's research and resource management staff for support and assistance with this study. The study was funded by a grant from the University of Wyoming–National Park Service Research Center.

LITERATURE CITED

ANDERSON, D. C., K. T. HARPER, and R. C. HOLMGREN 1982. Factors influencing development of cryptogamic soil crusts in Utah deserts. Journal of Range Management 35: 180–185.

BROTHERSON, J. D., and S. R. RUSHFORTH 1983. Influence of cryptogamic crusts on moisture relationships of soils in Navajo National Monument, Arizona. Great Basin Naturalist 43: 73–78.

CONOVER, W. J., and R. L. IMAN 1981. Rank transformations as a bridge between parametric and nonparametric statistics. American Statistician 35: 124–129.

________. 1983. A modern approach to statistics. John Wiley and Sons, Inc., New York. 497 pp.

DAUBENMIRE, R. 1970. Steppe vegetation of Washington. Washington Agricultural Experimental Station Technical Bulletin 62. 131 pp.

FINKLIN, A. I. 1986. A climatic handbook for Glacier National Park—with data for Waterton Lakes National Park. USDA Forest Service Intermountain Research Station General Technical Report INT-204. Ogden, Utah. 124 pp.

GLACIER NATIONAL PARK RECORDS. 1939. Correspondence between D. S. Libbey, Glacier Park Superintendent, and G. W. Noffsinger, President of the Park Saddle Horse Company, dated August 14, 1939. Archives. Glacier National Park, West Glacier, Montana.

HITCHCOCK, C. L., and A. CRONQUIST. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle. 730 pp.

KELSEY, R. G., and D. J. BEDUNAH 1989. Ecological significance of allelopathy for *Centaurea* species in the northwestern United States. Pages 10–32 *in* P. K. Fay and J. R. Lacey, eds., Knapweed symposium proceedings. Extension Service, Montana State University, Bozeman. EB 45.

KOTERBA, W. D., and J. R. HABECK 1971. Grasslands of the North Fork valley, Glacier National Park, Montana. Canadian Journal of Botany 49: 1627–1636.

LACEY, C. 1989. Knapweed management: a decade of change. Pages 1–6 *in* P. K. Fay and J. R. Lacey, eds., Knapweed symposium proceedings. Extension Service, Montana State University, Bozeman. EB 45.

LACEY, C. A., J. R. LACEY, T. K. CHICOINE, P. K. FAY, and R. A. FRENCH 1986. Controlling knapweed on Montana rangeland. Circular 311. Cooperative Extension Service, Montana State University, Bozeman. 15 pp.

LOCKEN, L. J., and R. G. KELSEY 1987. Cnicin concentrations in *Centaurea maculosa*, spotted knapweed. Biochemical Systematics and Ecology 15: 313–320.

MACK, R. N. 1986. Alien plant invasion into the Intermountain West: a case history. Pages 191–213 *in*: H. A. Mooney and J. A. Drake, eds., Ecology of biological invasions of North America and Hawaii. Springer-Verlag, New York.

________. 1989. Temperate grasslands vulnerable to plant invasions: characteristics and consequences. Pages 155–179 *in* J. A. Drake, H. A. Mooney, F. di Castri, R. H. Groves, F. J. Kruger, M. Rejmanek, and M. Williamson, eds., Biological invasions. John Wiley and Sons, New York.

MACK, R. N., and J. N. THOMPSON 1982. Evolution in steppe with few large, hooved mammals. American Naturalist 119: 757–773.

MARTINKA, C. J. 1983. Wildlife management in Glacier National Park: a regional perspective. Pages 48–56 *in* R. C. Scace and C. J. Martinka, eds., Towards the biosphere reserve: exploring relationships between parks and adjacent lands. U.S. Department of the Interior, National Park Service.

MUEGGLER, W. F., and W. L. STEWART. 1980. Grassland and shrubland habitat types of western Montana. USDA Forest Service General Technical Report INT-66. Ogden, Utah. 154 pp.

PYCHERT, R. C., and J. SKUJINS. 1974. Nitrogen fixation by blue-green algae–lichen crusts in the Great Basin desert. Soil Science Society of America Proceedings 38: 768–771.

STRINGER, P. W. 1973. An ecological study of grasslands in Banff, Jasper, and Waterton Lakes National Parks. Canadian Journal of Botany 51: 383–411.

TYSER, R. W., and C. H. KEY. 1988. Spotted knapweed in natural area fescue grasslands: an ecological assessment. Northwest Science 62: 151–160.

TYSER, R. W., and C. A. WORLEY. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). Conservation Biology. In press.

WATSON, A. K., and A. J. RENNEY. 1974. The biology of Canadian weeds. 6. *Centaurea diffusa* and *C. maculosa*. Canadian Journal of Plant Science 54: 687–701.

WEAVER, T., and B. WOODS. 1985. The exotic flora of Glacier National Park: a preliminary atlas. MSU Biology Report 37. Montana State University, Bozeman. 49 pp.

________. 1986. The exotic flora of Grand Teton National Park: an environmental atlas. MSU Report 38. Montana State University, Bozeman. 48 pp.

WILSON, S. D. 1989. The suppression of native prairie by alien species introduced for revegetation. Landscape and Urban Planning 17: 113–119.

YOUNG, J. A., R. A. EVANS, and J. MAJOR. 1972. Alien plants in the Great Basin. Journal of Range Management 25: 194–201.

Received 26 April 1991
Accepted 16 April 1992